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Association between insall-salvati index and anterior cruciate ligament tears: A cross-sectional study

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Abstract
Aim: There are many studies in the literature presenting morphological predisposing factors of anterior cruciate ligament (ACL) tears. Insall-Salvati index (ISI), which is widely used to measure patellar height, was investigated as a predisposing risk factor for the ruptures of ACL.
Material and Methods: Patellar tendon length (PTL), Patellar length (PL), and anterior tibial translation (ATT) were measured, and ISI values were calculated for the study and control groups. Knee magnetic resonance (MR) images of 33 patients who had undergone ACL reconstruction due to ruptured ACL, which is surgically confirmed (study group), and 90 patients who had undergone meniscus operation with surgically confirmed intact ACL (control group) were re-interpreted by two reviewers in terms of ISI and ATT values. Independent samples T-test was used to compare the results of the study and control groups. Additionally, intraclass correlation coefficient (ICC) values were presented to verify the interobserver difference between reviewers.
Results: PTL, ATT, and ISI values showed a statistically significant difference, and higher values were obtained in the study group than in the control group ($p<0,001$). There was excellent agreement between reviewers regarding PTL, PL, ISI, and ATT measurements.
Discussion: ISI had been used as an indicator of patellar dislocation. In this research, ISI was investigated to be in a relationship with ACL injuries in operated patients. The results of this study indicated higher ISI values in patients with ACL rupture. High ISI values might be a predisposing factor for ACL rupture and may be used in preventive medicine in terms of ACL injuries.

Keywords
Insall-Salvati Index, Anterior Cruciate Ligament, Patella, Knee Injuries, Knee

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Introduction

Anterior cruciate ligament (ACL) rupture is one of the most common injuries of the knee [1]. ACL injuries are particularly encountered more frequently in sports activities that involve jumping, knee rotation, and direction changes [2]. To develop preventive strategies against this injury, the investigators should be aware of the morphological and kinematic background of the function of ACL. In the literature, many morphological [3] and kinematic factors [4] have been investigated to be in a possible relationship with ACL injuries.

The Insall-Salvati index is widely used to indicate height and location anomalies of the patella. It is an easy method to apply and can be measured in lateral knee radiographs, as well as cross-sectional imaging techniques. Magnetic resonance (MR) imaging has the advantage of showing the cartilage and ligamentous structures better. The patellar tendon length (PTL) can reliably be measured on MR images, which provide higher sensitivity for predicting patellar instability compared with the other classic indices applied on radiographic images [5].

Some authors mentioned that during torsion, valgus, varus, flexion, or extension of the knee, translation is increased to prevent further stress on the patella and femur and leads to strain and injury of the ACL [6]. In the literature, patella alta has been hypothesized to be a risk factor for ACL rupture in children and teenagers [7]. Some recent studies indicated that PTL and ISI measurements were higher in ACL-ruptured patients in comparison with non-ruptured individuals [6, 8].

In this study, the authors aimed to verify the relationship between ISI and ACL tears by comparing surgically confirmed ACL-ruptured and ACL-intact patients who have undergone ACL reconstruction surgery and surgery for meniscal injuries, respectively. The interobserver differences of the measurements were also presented to indicate the reliability of the ISI and anterior tibial translation (ATT) values.

Material and Methods

Patients

This study has been approved by the institutional ethics committee, and the consent form from each patient has been waived due to the retrospective nature of the study. Between January 2020 and February 2023, 36 patients with ACL reconstruction surgery and 91 patients who have undergone surgery for meniscus injuries in the orthopedics and traumatology departments of our hospital have been considered to form the study group and the control group, respectively. Therefore, researchers aimed to compare surgically confirmed patient groups in terms of ACL integrity. Patients who were skeletally mature and had non-contact total ACL rupture were included in the study. 2 patients with traumatic ACL rupture (with tibial microfractures and traumatic bone marrow edema) and one patient under 18 years old were excluded from the study group. One patient with motion artifacts whose MR images could not be interpreted confidently in terms of ISI and ATT measurements was excluded from the control group. Patients with abnormalities of the tibial tuberosity (e.g., Osgood-Schlatter, history of osteotomy procedure) and moderate or severe osteodegeneration (Kellgren-Lawrence type 3 and 4) might influence the results and be planned to be excluded from the study. However, none of the patients has been encountered with this condition. After exclusions, 33 patients in the study and 90 patients in the control group were evaluated.

MR imaging protocol

All the patients underwent MR imaging, which was performed by a 1,5 T magnetic resonance machine (Magnetom Aera, Siemens, Erlangen, Germany) with standard (16-channel) knee coils. Turbo spin echo images with different sequences were obtained. The parameters (TR: Time of repetition, TE: Time of echo, NEX: Number of excitations, FOV: Field of View, ST: Slice thickness, VS: Voxel size, ms: milliseconds, mm: millimeters) used in each imaging series were as follows: Sagittal plane T1 weighted images (TR: 1110 ms, TE: 9,7 ms, NEX: 1, FOV: 180 mm, ST: 3 mm, VS: 0,5x0,5x3 mm), sagittal plane fat-saturated proton density imaging (TR: 3060 ms, TE: 38 ms, NEX: 1, FOV: 180 mm, ST: 3 mm, VS: 0,7x0,7x3 mm), coronal plane fat-saturated proton density imaging (TR: 2390 ms, TE: 20 ms, NEX: 2, FOV: 200 mm, ST: 4 mm, VS: 0,6x0,6x4 mm), axial plane proton density weighted fat saturated imaging (TR: 3440 ms, TE: 30 ms, NEX: 2, FOV: 180 mm, ST: 3 mm, VS: 0,6x0,6x3 mm).

Interpretation of the MR images

Two independent reviewers (a radiology resident with 3 years of experience and a radiologist with 18 years of experience) who were unaware of the surgical results and each other re-interpreted the MR images in different monitors. The reviewers used the same picture archiving and communication system (PACS) (Akgün PACS Viewer v7.5, Akgün Software, Ankara, Turkey) to examine the digital imaging and communication in medicine (DICOM) images of the patients, and the image dataset had randomized (including patient and control groups randomly) by another researcher before the examination of the reviewers. Non-fat-suppressed T1 weighted sagittal plane images were used to perform the ISI and ATT measurements to view the anatomical background. The mid-sagittal plane was used to depict the maximum lengths of the patella and patellar tendon. In addition, non-fat-suppressed T1W images provided good anatomical detail to understand the insertions of the patellar tendon into the patella and tibial tuberosity.

ISI and ATT measurements

Patellar tendon length (PTL) was measured as the length of the posterior surface of the patellar tendon from the lower pole of the patella to its insertion on the tibia. Patellar length (PL) was measured as the greatest superoinferior pole-to-pole length. The PTL/PL ratio was calculated as the Insall-Salvati ratio (Figure 1). Anterior tibial translation (ATT) was measured as described by Chiu [9]. The midsagittal plane of the lateral compartment of the knee was used to measure the ATT. The distance between two parallel lines drawn perpendicular to the image frame, the tangent line to the posterior contour of the lateral femoral condyle, and the posterior contour of the proximal tibial condyle in the same image, was measured as the ATT (Figure 2). Each reviewer measured PTL, PT, and ATT twice and noted the average value as the measurement result. The measured values were noted by the reviewers using two decimals after the comma, which was indicated by the PACS system automatically.

Statistical analysis

All statistical analyses were achieved using IBM SPSS Statistics

for Windows version 22.0 /IBM Corp., Armonk, NY, USA). The data distribution normality analysis was tested by the Shapiro-Wilk test, and parametric test procedures were applied after the quantitative data showed normal distributions. Box plot analyses are used to show the data distributions of the measured values. Intraclass correlation coefficient (ICC) values were measured to indicate the interobserver differences. According to the ICC values, less than 0,50, 0,50-0,75; 0,75-0,90,>0,90 indicated poor, moderate, good, and excellent agreement, respectively, in terms of ranking the agreement between reviewers as described by Koo and Li [10]. The PTL, PT, ISI, and ATT values were compared between the study and control groups using the independent T-test. The p values <0,05 were accepted to indicate the significance of the difference in all statistical analyses.

Ethical Approval

This study has been approved by the institutional ethics committee (Ethics Committee of Clinical Research of Erzincan Binali Yıldırım University (Date: 2023-03-07, No: 2023-06/3).

Results

Knee MR images of 101 male and 22 female patients were re-interpreted. The mean age was 32,95 ± 10,36 years for the patients involved in this study. 60 right-sided and 63 left-sided knee MR images were included in this investigation. Each operated knee belonged to a different patient, and there was no operated patient for both knees in the period of the study. Table 1 shows the demographic data of the patients involved in the study.

Table 1. Demographic data of the patients

	Study group (n=33)	Control group (n=90)
Sex (n)	32 Males, 1 Female	69 Males, 21 Females
Age*	27.36 ± 8.45	35.00 ± 10.29
Side (n)	14 Left, 19 Right	49 Left, 41 Right

*According to the independent samples T-test, there was a significant difference between the study and control groups according to age (p<0.001)

Table 2. Results of the PTL, PL, ISI, and ATT measurements

	Study group (Mean ± SD)	Control group (Mean ± SD)	p value
PTL	48.52 ± 3.43	44.93 ± 5.27	<0.001
PL	43.20 ± 2.18	43.49 ± 4.08	0.619
ISI	1.12 ± 0.08	1.03 ± 0.13	<0.001
ATT	9.09 ± 2.16	2.89 ± 1.57	<0.001

PTL: Patellar tendon length, PT: Patellar length, ISI: Insall-Salvati ratio, ATT: Anterior tibial translation, SD: Standard deviation

Table 3. Intraclass correlation coefficient values regarding PTL, PL, ISI, and ATT measurements

	ICC	95% CI	
		Lower Bound	Upper Bound
PTL	0.990	0.981	0.994
PL	0.986	0.980	0.990
ISI	0.983	0.975	0.988
ATT	0.992	0.987	0.995

ICC: Intraclass correlation coefficient, CI: Confidence interval, PTL: Patellar tendon length, PT: Patellar length, ISI: Insall-Salvati ratio, ATT: Anterior tibial translation, SD: Standard deviation

PTL, PL, ISI, and ATT values measured by each reviewer indicated ICC values as 0.990, 0.986, 0.983, and 0.992, respectively, and showed almost perfect agreement between the reviewers (Table 2).

There was a statistically significant difference between the study and control groups according to PTL, ISI, and ATT values (p values were <0.001 for all three parameters). No statistically significant difference was observed regarding the PL measurements (Table 3). The data distributions were presented for PTL, PT, ISI, and ATT values (Figure 3).

Figure 1. The patellar tendon length (PTL) and patellar length were measured as 46.86 and 43.43, respectively, in this patient on sagittal plane T1 weighted magnetic resonance image. The ISI ratio (PTL/PL) was calculated as 1.07 in this patient

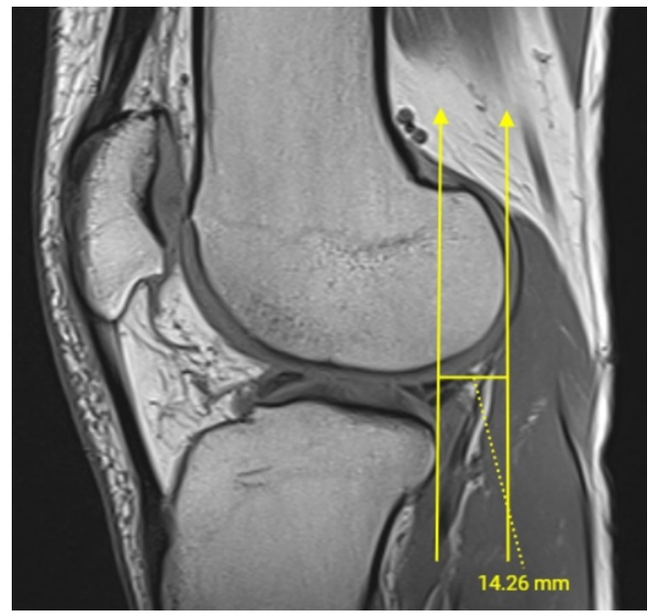

Figure 2. The distance between the tangent line to the posterior contour of the lateral femoral condyle and the posterior contour of the proximal tibial condyle indicated the anterior tibial translation on the T1 weighted plane which shows the midsagittal slice of the lateral knee compartment

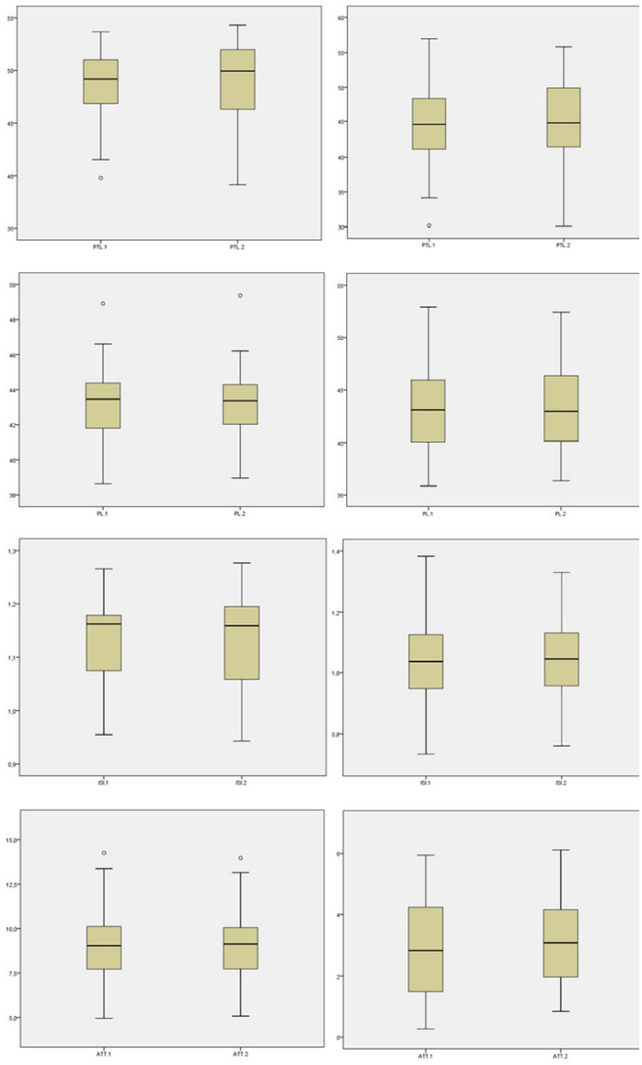

Figure 3. The left column shows the study group and the right column presents the control group regarding the data distributions of reviewer one and reviewer 2 in terms of the parameters measured in the study (PTL: Patellar tendon length, PT: Patellar length, ISI: Insall-Salvati ratio, ATT: Anterior tibial translation)

Discussion

This study verified the difference between patients with and without ACL rupture in terms of PTL, ISI, and ATT values with high inter-observer agreements. Higher PTL, ISI, and ATT values were measured in patients with ACL injuries. The theoretical background and observations in the past literature encouraged some authors to consider the effect of ISI on ACL rupture and are worth discussing. Degnan et al. hypothesized that the factors that predispose to ACL ruptures may also predispose to relative patella alta. To emphasize this thought, they suggested that females have a higher incidence of ACL injuries and also a higher incidence of patella alta than male individuals. This situation made the authors think that there is a common predisposing factor for both entities [7]. In addition, females have weaker hamstring muscles compared to males, as mentioned in the literature, and a higher strength ratio between the quadriceps and hamstring muscles has been indicated to provide greater strain in the ACL [11-12]. Singerman et al. reported that the subluxation of a high-riding patella might partly be explained by the association between genitofemoral contact and the medial-lateral component of the contact force. In addition, the authors indicated that any procedure that shifts the patella superiorly to the femoral condyles or tibiofemoral joint line would tend to increase this force and, therefore, renders the tendency to subluxation of the patella [13]. The ratio of PTL to PL is a commonly used and reliable index to measure and determine the patellar height [14]. Insall-Salvati ratio was not only applied to consider the patella alta or baja but studied as a distinct parameter to be related to chondromalacia patella by some authors [15]. On the other hand, there are not many studies in the literature using ISI to be in relationship with ACL injuries via MR imaging and presenting interobserver differences between the reviewers.

The factors which play a role in ACL injuries are investigated in many studies. Morphologically, multiple factors have been studied to be in a possible relationship with ACL ruptures, including tibial plateau characteristics, Q angle, alpha angle, femoral intercondylar notch geometry, condylar width, bone to cartilage height, cartilage slope [3, 16]. In addition to the morphological factors, the genetic background was also investigated by some authors [17].

Some papers mention the possible relationship between ISI and ACL injuries, including the PTL and PT values to investigate as distinct parameters. Degnan et al. measured ISI on knee MR images of children who were arthroscopically proven to have ACL tears, and PTL and IS values were significantly higher in the ACL-ruptured group [7]. Akgün et al. measured PTL and PT on the MR images of an adult population, and increased PTL and ISI values were reported in patients with ACL injuries compared with the control group [8]. Güven et al. evaluated the MR images of skeletally matured patients and revealed significantly higher values in patients with ACL injury about PTL, PL, ISI, and ATT values compared with the control group [6]. The results of this current study were very similar to Güven et al. in terms of higher values according to PTL, ISI, and ATT measurements in the study group. Additionally, ICC values showed a high-grade agreement between reviewers, which strengthens the results and underlines this association between ISI and ACL injuries.

On the other hand, there were studies with negative or opposite results in the literature, and it is important to discuss to determine the exact relationship between ISI and ACL tears. Gültekin et al. indicated no significant difference between patients with and without ACL tears according to ISI measurements in their study [18]. Lin et al. used lateral radiographs to compare patients with and without ACL tears and reported significantly lower values of ISI measurements in patients with ACL tears than in the control group [19].

Limitation

There were limitations of the study to discuss before interpreting the results of this investigation. Although all of the patients in the study and control group were surgically confirmed in terms of the integrity of the ACL, the number of patients was relatively small, and larger patient groups are needed to confirm the results of the current study. The mean age difference between the patient and control groups should also be another factor to mention before determining the results. The body mass indexes of the patients, which are known to be related to considering

the axial force to the knee, were not taken into account in this study. The male dominance in the study group is also an important issue to discuss and should be kept in mind before the evaluation of the results. In addition, the absence of data explaining the mechanism of ACL rupture in this investigation can also be considered another limitation of the study.

Conclusion

The biomechanical effect and kinematic alterations with higher PTL and ISI should be better understood to rationalize the mechanism behind these results of the study. Negative results should also be considered to reveal the exact relationship between the patellofemoral geometry and the effect of the specific morphological conditions, which might be a predisposing factor for ACL injuries. Many more studies, including statical evaluations with knee imaging and biomechanical models supported by kinetic tests of the knee joint, may be helpful to analyze this relationship further.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or compareable ethical standards.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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